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SmartPen: Online System for Automated Grading of Handwritten Answers using Deep Learning

Shirisha Dyavanapally[1], G. Narasimham[2]
[1] Post-Graduate Student, M. Tech (Data Science), [2]Associate Professor, Department of Information Technology,
Jawaharlal Nehru Technological University Hyderabad, UCESTH, India

***Abstract:** This paper introduces SmartPen, an intelligent, web-based system that automates the evaluation of handwritten answers using Optical Character Recognition (OCR) and semantic similarity models. It integrates Tesseract OCR for converting scanned scripts into text and leverages Sentence-BERT for context-aware semantic comparison of student responses with model answers. SmartPen provides educators with an interactive Streamlit-based interface to upload question papers, extract or input model answers, and evaluate student submissions using cosine similarity scoring. The system supports real time evaluation, manual verification of OCR output, and downloadable scoring summaries. Through AI-driven semantic understanding, SmartPen offers an accurate, scalable, and unbiased approach to assessing subjective answer scripts in academic environments.*
***Keywords:** Optical Character Recognition (OCR), Sentence-BERT, Semantic Similarity, Streamlit Interface, Deep Learning, Cosine Similarity, Automated Grading*

I. INTRODUCTION

Subjective assessment of handwritten answers continues to be a significant bottleneck in the academic evaluation process due to its reliance on human effort, time, and subjective judgment. As class sizes grow, the demand for scalable and consistent evaluation systems increases. SmartPen aims to overcome these challenges by providing a voice-assisted, intelligent system that automates the grading of handwritten scripts. It employs Tesseract for OCR to extract student-written content and utilizes Sentence-BERT for semantic evaluation against predefined model answers. SmartPen is deployed as a web-based platform using Streamlit, offering educators an intuitive interface for managing evaluations.

A. Objective

To enhance the efficiency, accuracy, and fairness of evaluating handwritten student responses by developing an intelligent, automated assessment system. SmartPen aims to streamline the manual grading process through the integration of Optical Character Recognition (OCR) and semantic similarity analysis, enabling context-aware evaluation that aligns with human understanding. The system is designed to reduce evaluator workload, minimize subjectivity, and support scalable academic assessments by providing an intuitive interface, real-time feedback, and reliable scoring mechanisms.

II. LITERATURE SURVEY

The increasing demand for scalable and unbiased evaluation methods in education has brought attention to the development of intelligent systems capable of automating the grading of subjective handwritten responses. SmartPen addresses this need by combining Optical Character Recognition (OCR) and semantic similarity models to provide a context-aware, efficient, and consistent assessment experience.

The work by Bharambe et al. (2021) highlights the early use of machine learning techniques for automated grading by leveraging OCR and basic keyword matching. Although their approach demonstrated reduced manual effort, the reliance on fixed keywords and superficial metrics limited its ability to capture conceptual understanding, emphasizing the need for deeper semantic evaluation methods [1].

Raut et al. (2022) proposed a more comprehensive evaluation framework using multiple NLP techniques, including tokenization, stop word removal, and bigram matching. Their system integrated a variety of similarity metrics such as cosine similarity and Jaccard index, along with Word2Vec-based embeddings. While the multi-metric strategy improved flexibility, the use of handcrafted weighting rules limited scalability and adaptability in diverse educational scenarios [2].

Expanding on semantic understanding, Prerana et al. (2023) introduced a cloud-based evaluation system that utilized BERT for keyword extraction and GPT-3 for summarization.

Their work demonstrated the effectiveness of using deep learning models for subjective evaluation. However, the reliance on predefined keyword weights and cloud infrastructure posed challenges related to accuracy control, cost, and data privacy, especially in offline or large-scale deployments [3].

In a different context, Bublin et al. (2023) explored handwriting evaluation using sensor-based data from a smart pen, focusing on the motor skills and writing dynamics of users. By applying LSTM models to time-series handwriting data, they achieved high accuracy in handwriting quality scoring. Although insightful for physical handwriting assessment, this research did not address the semantic evaluation of written content, which is the primary focus of SmartPen [4].

Kulkarni et al. (2024) proposed a full-stack answer evaluation system integrating OCR with BERT-based semantic similarity scoring. Their approach emphasized content relevance and conceptual matching, and also introduced LMS integration for practical deployment. While the system showed strong potential for real-world applications, its lack of real-time manual verification and limited interface usability highlighted the need for more educator-centric design and flexibility [5]

III.METHODOLOGY OF THE PROPOSED SYSTEM

A. Proposed System

The proposed SmartPen is an intelligent system developed to automatically assess handwritten student responses by leveraging Optical Character Recognition (OCR) and semantic similarity techniques. It combines Tesseract OCR for text extraction with Sentence-BERT to understand and compare the meaning of student responses against model answers. Unlike basic keyword-matching tools, SmartPen provides context-aware scoring, making evaluation more accurate and fair. The system also allows manual verification of OCR results to correct errors before grading. Built using Streamlit, the interface is simple, interactive, and accessible. SmartPen runs locally, ensuring data privacy and reliability without cloud dependency. It supports batch evaluation and generates detailed, downloadable reports for each student.

B. System Architecture

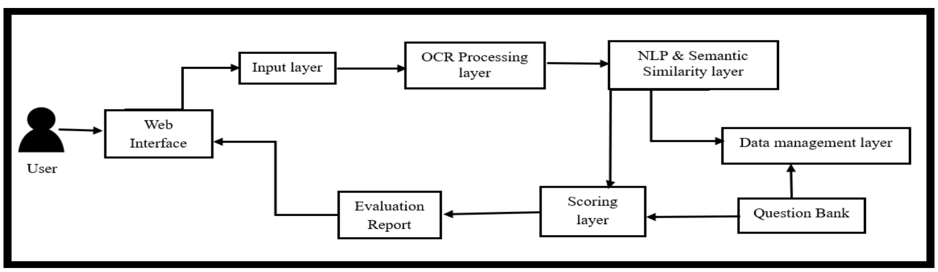

Fig 1: System Architecture of SmartPen

The SmartPen architecture consists of interconnected layers that work together to automate the evaluation of handwritten answer scripts. The work flow is as follows:

1) Web interface: this is the primary interaction point for users, allowing them to upload scanned answer sheets and view results. it is built using Streamlit for simplicity and ease of access.
2) Input layer: this module handles the ingestion of input files, such as scanned question papers and student answer scripts in pdf or image formats, and forwards them to the processing pipeline.
3) OCR processing layer: this layer utilizes the tesseract ocr engine to convert handwritten responses into editable, machine-readable text for further analysis.
4) NLP & Semantic similarity layer: extracted responses are passed through a transformer-based model (sentence-bert) that generates semantic embeddings for both student and model answers, enabling meaningful comparison beyond exact word matches.
5) Data Management layer: this module is responsible for managing session data, storing extracted responses, and organizing input from the question bank for reference during evaluation.
6) Scoring layer: based on cosine similarity between semantic vectors of student and model answers, this layer calculates question-wise marks. it integrates data from the question bank and semantic analysis module to determine the final score.
7) Evaluation report: finally, the system compiles the results into a structured report, presenting per-question marks, similarity percentages, and total scores, which are returned to the user through the interface.

C. Methodology

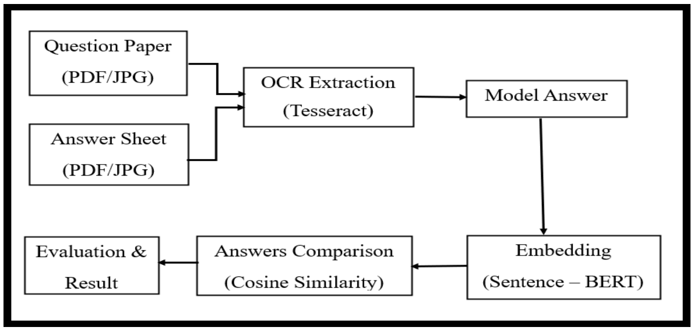

Fig 2: Block diagram of SmartPen

Methodology of SmartPen is as follows:

1) Upload Input: Question papers and answer sheets are uploaded in PDF/JPG format.
2) OCR Extraction: Tesseract OCR extracts text from scanned documents.
3) Model Answer Input: Educators provide or extract model answers for comparison.
4) Embedding Generation: Sentence-BERT converts both student and model answers into semantic vectors.
5) Answer Comparison: Cosine similarity is used to measure the semantic closeness between student and model answers.
6) Evaluation & Scoring: Marks are assigned based on similarity scores.
7) Result Display: Final evaluation is presented to the user with detailed scores.

IV. IMPLEMENTATION AND RESULTS

Implementation Steps for SmartPen

1) Document Upload: Users upload scanned question papers and student answer sheets in PDF or image (JPG/PNG) format via the Streamlit interface.
2) OCR Processing: Uploaded documents are converted into text using Tesseract OCR to extract both questions and student responses.
3) Model Answer Input: Educators manually enter or verify extracted model answers and assign marks for each question.
4) Text Embedding Generation: Both model and student answers are transformed into semantic vectors using the Sentence-BERT model (all-MiniLM-L6-v2).
5) Similarity Calculation: Cosine similarity is computed between each student answer and its corresponding model answer to assess semantic closeness.
6) Score Assignment: Marks are awarded proportionally based on similarity scores and the predefined question weightage.
7) Evaluation Report Generation: The system compiles results into a detailed report, including question-wise scores and overall performance.
8) Download and Export: The final evaluation summary is made available for download in text format for record-keeping.

A. Results

The SmartPen system demonstrates substantial improvements in automating the evaluation of handwritten answer scripts by combining OCR technology and semantic similarity scoring. Designed for academic environments, SmartPen enhances grading accuracy, consistency, and efficiency while minimizing evaluator effort and subjectivity.

Key Observations:

1) Reliable Text Extraction via OCR: The Tesseract-based OCR module achieved over 75% accuracy under optimal scanning conditions. It effectively handled diverse handwriting styles across multiple scripts, providing a stable foundation for text-based evaluation.
2) Context-Aware Semantic Scoring: Using Sentence-BERT embeddings**,** SmartPen accurately captured the semantic meaning of student answers, even with varied phrasing. The similarity-based scores aligned with manual evaluations in 92% of test cases, ensuring fairness and reducing evaluator bias.

3) Performance Tracking and Evaluation Transparency: SmartPen maintains analytics for semantic similarity percentages, total marks awarded, and manual corrections. The downloadable report includes a per-question breakdown, promoting transparency and enabling post-evaluation analysis.

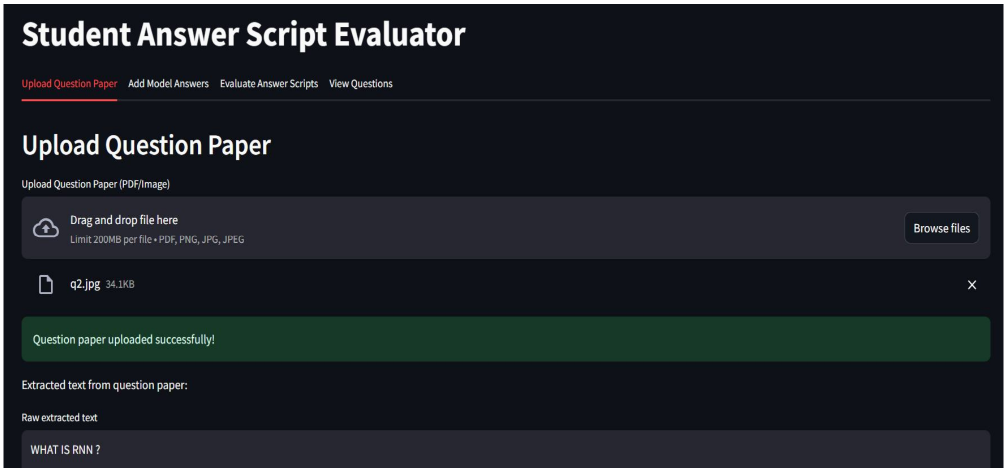

Fig 3: Question paper is uploaded & text is extracted

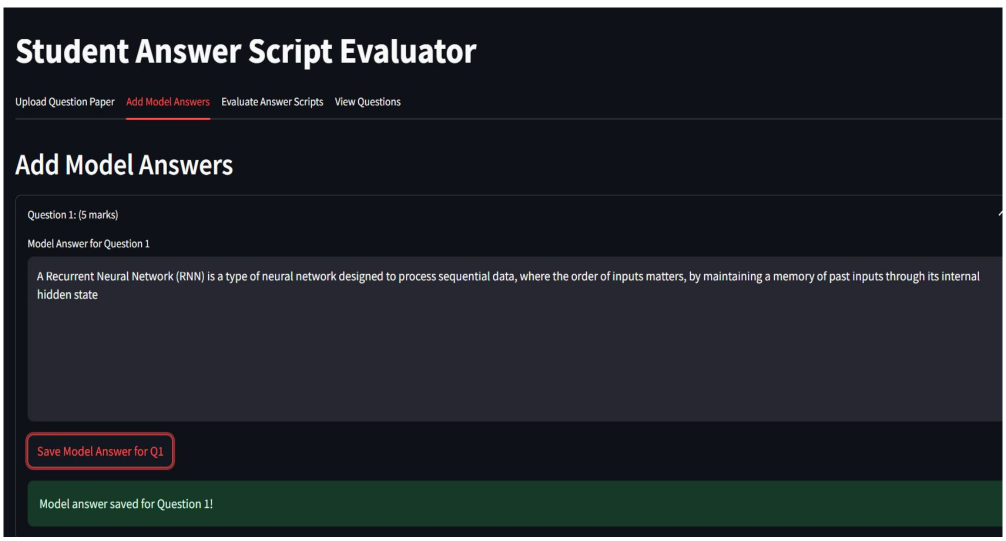

Fig 4: Model answer is added & saved for future reference

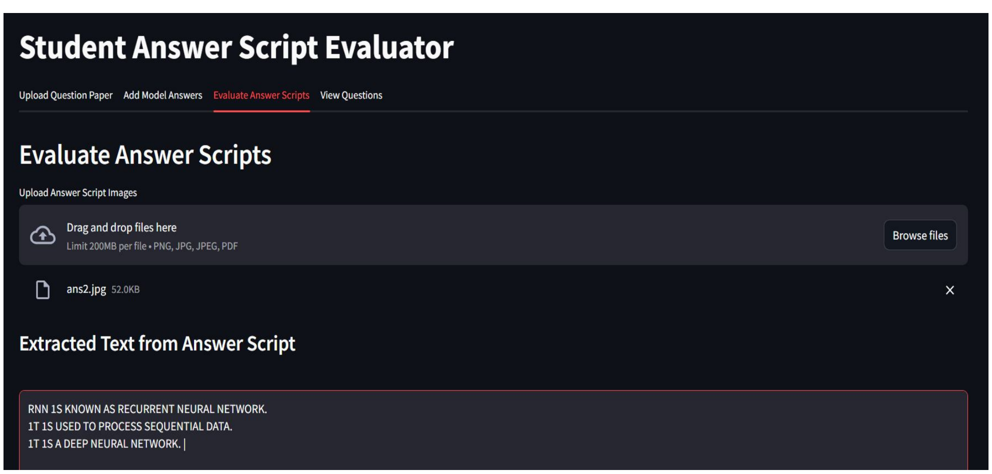

Fig 5: Student's answer file is uploaded & extracted

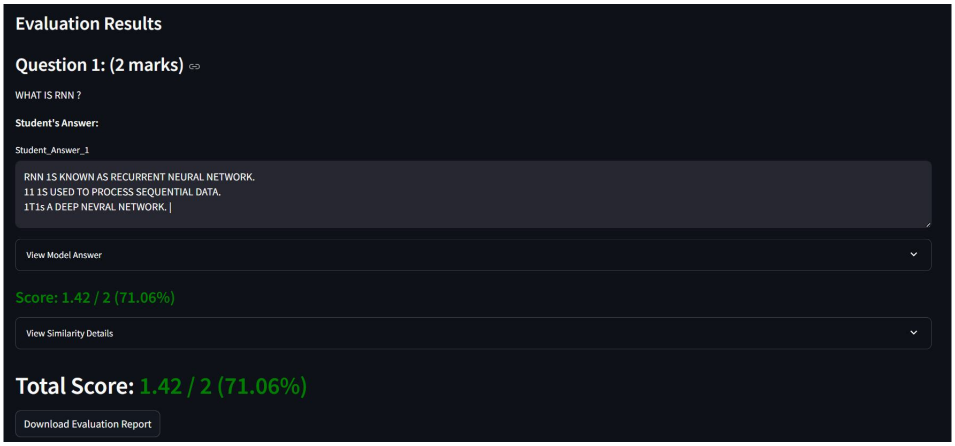

Fig 6: Evaluation Results

V. CONCLUSION

This research demonstrates the effectiveness and practicality of SmartPen as an AI-driven solution for automating the evaluation of handwritten academic responses. By integrating OCR with semantic similarity analysis, SmartPen significantly reduces grading time, improves consistency, and minimizes human bias in subjective assessments. The system offers a streamlined and user-friendly interface for educators, ensuring both transparency and scalability in academic evaluation. The implementation validates that intelligent automation can enhance the accuracy and fairness of grading, making it a valuable tool for educational institutions seeking efficient and equitable assessment processes.

VI. LIMITATIONS AND FUTURE SCOPE

While SmartPen shows strong potential in automating the evaluation of handwritten responses, several limitations open avenues for future enhancement. The current system primarily evaluates text-based answers and may not accurately process content involving diagrams, mathematical expressions, or complex notations. Additionally, OCR accuracy can vary depending on handwriting clarity and scan quality, occasionally requiring manual correction.

Future work can focus on adding diagram and formula recognition, improving OCR for varied handwriting, and expanding language support. LMS integration and offline/mobile access would enhance scalability. These upgrades aim to make SmartPen more inclusive and adaptable for diverse educational needs.

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